

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

MULTI-LEVEL TECHNIQUE FOR STIFFNESS AND STRENGTH CALCULATIONS OF WOVEN FABRIC COMPOSITE PLATE AND SHELL STRUCTURES

Ahmet Altekin-Lieutenant Junior Grade, Turkish Navy

B.S., Turkish Naval Academy, 1994

Master of Science in Mechanical Engineering-June 2001

Advisor: Young W. Kwon, Department of Mechanical Engineering

The stiffness and strength behavior of the woven fabric composite materials mainly depend on the properties of the fiber and matrix materials. A technique was developed to design and analyze woven fabric composites based on the micro-level properties of the fiber and matrix materials. The technique is based on the bilateral relationships among the fiber/matrix materials, the unidirectional composite (strand), the woven fabric layer and the laminated composite structure as in the given order. Simplified and efficient analytical models were developed for the relationship between any subsequent levels. The technique is used to predict the structural level stiffness and strength in terms of material and geometric configuration of the woven fabric and lamination. Progressive damage/failure can also be simulated at the fiber and matrix level by using this technique.

DoD KEY TECHNOLOGY AREA: Materials, Process and Structures

KEYWORDS: Multilevel Technique, Woven Fabric Composite, Fiber, Matrix, Strand, Plate, Shell, Volume Fraction, Damage Size, Undulation Angle, Failure Criteria

ADAPTIVE MULTI-LAYER LMS CONTROLLER DESIGN AND ITS APPLICATION TO ACTIVE VIBRATION SUPPRESSION ON A SPACE TRUSS

Timothy A. Barney-Lieutenant, United States Navy

B.S., Eastern Michigan University, 1993

Master of Science in Mechanical Engineering-June 2001

Advisors: Young S. Shin, Department of Mechanical Engineering

Brij N. Agrawal, Department of Aeronautics and Astronautics

This thesis develops an adaptive controller that actively suppresses a single frequency disturbance source at a remote position and tests the system on the NPS Space Truss. The experimental results are then compared to those predicted by an ANSYS finite element model. The NPS space truss is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment mounted at its extremities. One of two installed piezoelectric actuators and an Adaptive Multi-Layer LMS control law were used to effectively eliminate an axial component of the vibrations induced by a linear proof mass actuator mounted at one end of the truss. Experimental and analytical results both demonstrate reductions to the level of system noise. Vibration reductions in excess of 50dB were obtained through experimentation and over 100dB using ANSYS, demonstrating the ability to model this system with a finite element model. This thesis also proposes a method to use distributed quartz accelerometers to evaluate the location, direction, and energy of impacts on the NPS space truss using the dSPACE data acquisition and processing system to capture the structural response and compare it to known reference signals.

DoD KEY TECHNOLOGY AREA: Space Vehicles, Modeling and Simulation

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KEYWORDS: Active Vibration Suppression, Piezoceramic Actuators, Impact Analysis, Adaptive Controller, LMS

COMPUTATIONAL MECHANICS OF THE FULL-SCALE AND MODEL-SCALE ROLL-ON, ROLL-OFF (RORO) STERN RAMP AND EXPERIMENTAL MODAL ANALYSIS OF THE MODEL-SCALE RAMP AND SUPPORT

James E. Buckley-Lieutenant, United States Navy

B.S., Oregon State University, 1994

Master of Science in Mechanical Engineering-June 2001

Advisor: Joshua H. Gordis, Department of Mechanical Engineering

It has been determined that current stern ramp designs lack adequate structural integrity during Sea State Three roll-on, roll-off (RORO) operations. Therefore, passive isolation between the stern ramp and the RORO discharge facility (RRDF) is being investigated as a means of reducing ramp stress levels. A coupled hydro-structural simulation model of the combined ship-ramp-RRDF is under development in order to evaluate candidate isolator technologies. This thesis documents a thorough study of several stern ramp finite element models in order to ascertain the suitability of these models for use in the simulation model. Additionally, an experimental facility is being developed to simulate, at model scale, RORO operations. This thesis also documents the finite element analysis and experimental modal analysis of the primary structural components of the facility, specifically the scale model stern ramp and its support.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Roll-On, Roll-Off, RORO, Stern Ramp, Isolation

MODELING OF SHIPBOARD SMOKE PROPAGATION WITH A FORCED COUNTER-FLOW AIR SUPPLY

Garrett J. Farman-Lieutenant Commander, United States Navy

B.S., University of Rochester/Engineering, 1990

Master of Science in Mechanical Engineering-June 2001

Advisor: Matthew D. Kelleher, Department of Mechanical Engineering

The propagation of fire-generated smoke with a counter-flow air supply in a horizontal arrangement of shipboard compartments and passageways was modeled using a computational fluid dynamics program generated by Computational Fluid Dynamics Research Corporation. This study was based on a large-scale live fire experiment performed by Naval Research Laboratory on the ex-USS SHADWELL. All simulations were evaluated at steady state conditions. A constant velocity counter-flow air supply was introduced into the model structure. The counter-flow air velocities used were 0.5, 1, and 2 m/s. This study used a Computational Fluid Dynamics combustion module to simulate a 620 kW fire generated by the complete combustion of propene gas from a burn pan in the space. Carbon dioxide from the fire was tracked throughout the structure to model smoke propagation. Seven simulations were performed with adiabatic and isothermal bulkhead, deck and overhead boundary conditions. Simulation smoke propagation results were consistent with experimental observations. Figures depicting temperature distribution, carbon dioxide distribution and mixture flow patterns at specified locations are provided in the report. The goal of this study is to evaluate the effectiveness of computational fluid dynamics modeling of smoke propagation in a shipboard space with a counter-flow air supply.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Smoke, Smoke Modeling, Smoke Propagation, Smoke Spread, Smoke Movement, Computational Fluid Dynamics, Control Shipboard Smoke, Fire Induced Flow, Fire Spread, Field Modeling, Damage Control, Convection, Forced Air Supply

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DETERMINATION OF INCLUSION CHEMISTRY AND SIZE DISTRIBUTION IN STEEL WELDMENTS BY ANALYTICAL ELECTRON MICROSCOPY

**Craig A. Hackstaff-Lieutenant, United States Navy
B.S., United States Naval Academy, 1994**

Master of Science in Mechanical Engineering-June 2001

Advisor: Alan G. Fox, Department of Mechanical Engineering

The U. S. Navy has been concerned about reducing the number of inclusions in steel weldments to increase the toughness of the weld metal. Research has shown that particular inclusions can nucleate the acicular ferrite microstructure in the weld metal, which can increase toughness without compromising strength. The present study investigated the inclusion chemistry and size distribution in aluminum-deoxidized C-Mn steel weldments. The results showed that the addition of aluminum to the C-Mn weld metal will produce inclusions, that can nucleate acicular ferrite by epitaxy, and that the number and volume fraction of inclusions is reduced. This indicates that aluminum deoxidation of steel weld metal can have positive benefits for C-Mn weld metal strength and toughness.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Acicular Ferrite, Shielded Metal Arc Welding, C-Mn Steel Weldments, Non-metallic Inclusions

AUV STEERING PARAMETER IDENTIFICATION FOR IMPROVED CONTROL DESIGN

**Jay H. Johnson-Lieutenant, United States Navy
B.S., University of Kansas, 1993**

Master of Science in Mechanical Engineering-June 2001

Advisor: Anthony J. Healey, Department of Mechanical Engineering

Any effort to provide precision control for an Autonomous Underwater Vehicle requires an accurate estimation of both the vehicle's physical and hydrodynamic parameters. Here a vehicle model for controlled steering behaviors was developed and the hydrodynamic parameters were calculated from actual data obtained from operation. The steering equation parameters are based on a least squares fit to sideslip and turn rate data using maximum likelihood of batch processing. In this way, a more accurate simulation has been found for the development of a track controller that stably drives the vehicle between mission waypoints. Prediction accuracy of the model was better than ninety-five percent over the data set used.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Aircraft

KEYWORDS: Underwater Vehicle, AUV, Control, System Identification, Autonomous Systems, Robotics

VERTICAL PLANE RESPONSE OF SURFACE SHIPS IN CLOSE PROXIMITY TOWING

**Christopher A. Nash-Lieutenant, United States Navy
B.S., United States Naval Academy, 1994**

Master of Science in Mechanical Engineering-June 2001

Advisor: Fotis A. Papoulias, Department of Mechanical Engineering

The purpose of this thesis is to analyze the vertical plane response of surface ships in close proximity towing. The problem is formulated by using the heave and pitch equations of motion in regular waves. The vertical motion of the leading and trailing ship attachment points is calculated. The relative motion between these points is then matched through a notional spring/damper model of the connection. This allows calculation of the complete response amplitude operators for the two ships in terms of their relative motion and connection force. Parametric studies are conducted in terms of connection spring and damper characteristics, speed, and sea direction. Regular wave results are extended in standard fully developed

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random seas. A notional example provides insight into future studies necessary to validate the close-proximity towing concept.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Slice, Kaimalino, Seakeeping, Swath, RAO

A HOT-STAGE ATOMIC FORCE MICROSCOPE FOR THE MEASUREMENT OF PLASTIC DEFORMATION IN METALLIC THIN FILMS DURING THERMAL CYCLING

Thomas E. Shultz-Lieutenant, United States Navy

B.A., Occidental College, 1994

Master of Science in Mechanical Engineering-June 2001

Advisor: Indranath Dutta, Department of Mechanical Engineering

An Atomic Force Microscope is equipped with a hot-stage and a vacuum system in order to enable *in-situ* studies of plastic deformation and interfacial sliding of thin metallic films on Si substrates during thermal cycling. The apparatus can reach sample temperatures of 100°C while maintaining optimum resolution. The system will allow future *in-situ* thermal cycling experiments on microelectronic devices in a protected environment to provide insight into the role of plastic deformation in metallic thin films on the stability of future generations of device structures. The details of the design, along with the performance limitations of the system are discussed. Preliminary results demonstrating the performance of the system at an elevated temperature are presented. Limited *post-situ* results from direct measurement of the plastic deformation of thin Cu films on Si substrates induced by thermal cycling are also presented, primarily with the objective of establishing the need for detailed *in-situ* studies. While artifacts such as permanent dimensional changes of the film are observed *post-situ*, a detailed mechanistic understanding of the interaction between the temperature-dependent stress state of the film and the resultant inelastic deformation within the film and at the interface can only be obtained through *in-situ* experiments.

DoD KEY TECHNOLOGY AREA: Electronics, Materials, Processes, and Structures

KEYWORDS: Atomic Force Microscopy, Creep Mechanisms, Hot-Stage, Interfacial Sliding, Microelectronic Devices, Thin Films, Vacuum System

DEVELOPMENT OF EXPERIMENTAL FACILITY FOR ROLL-ON ROLL-OFF RAMP ISOLATION DYNAMICS

Richard A. Trevisan-Lieutenant, United States Navy

B.S., Marquette University, 1993

Master of Science in Mechanical Engineering-June 2001

Advisors: Joshua H. Gordis, Department of Mechanical Engineering

Fotis A. Papoulias, Department of Mechanical Engineering

It has been determined that a high stress state occurs in the Roll-on Roll-off (RORO) ship offload stern ramp during vehicle transfers in Sea State 3 conditions. Motion compensation systems (i.e. isolators) between the ramp and the barge (RRDF) are needed to minimize the high stress levels in the ramp. This thesis documents the design, analysis, and construction of a facility to evaluate the performance of candidate isolation systems to be used to minimize ramp stresses. The facility consists of a fabricated aluminum scale ramp model designed to mimic the structural dynamics of a full-scale ramp, a fabricated supporting structure and an actuator that simulates wave motion inputs to the barge-end of the isolator.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Isolation, Roll-on, Roll-off, RORO, Stern Ramp